HIGH-STRENGTH CERAMIC SUBSTRATES FOR THICK-FILM SENSOR APPLICATIONS

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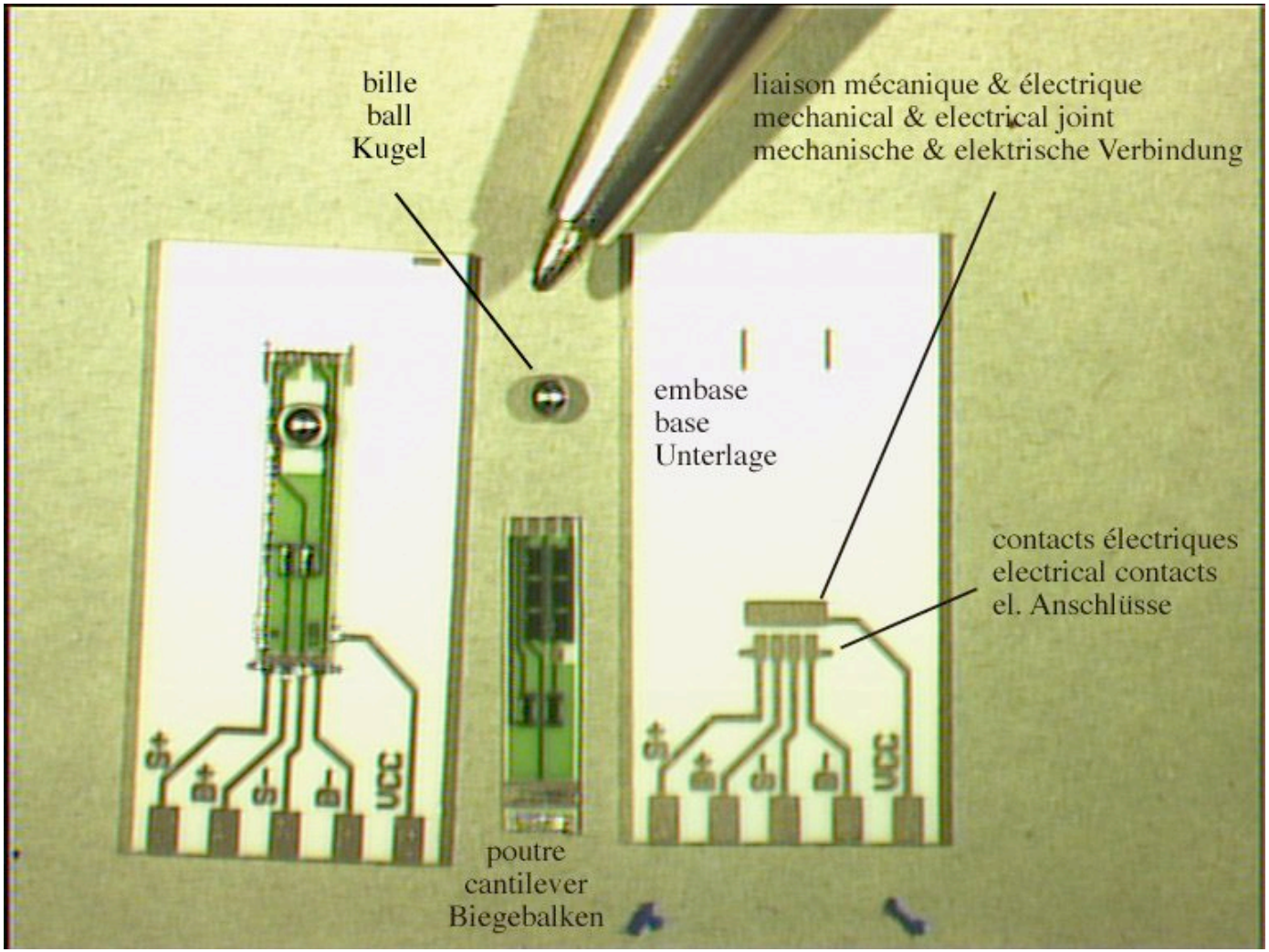
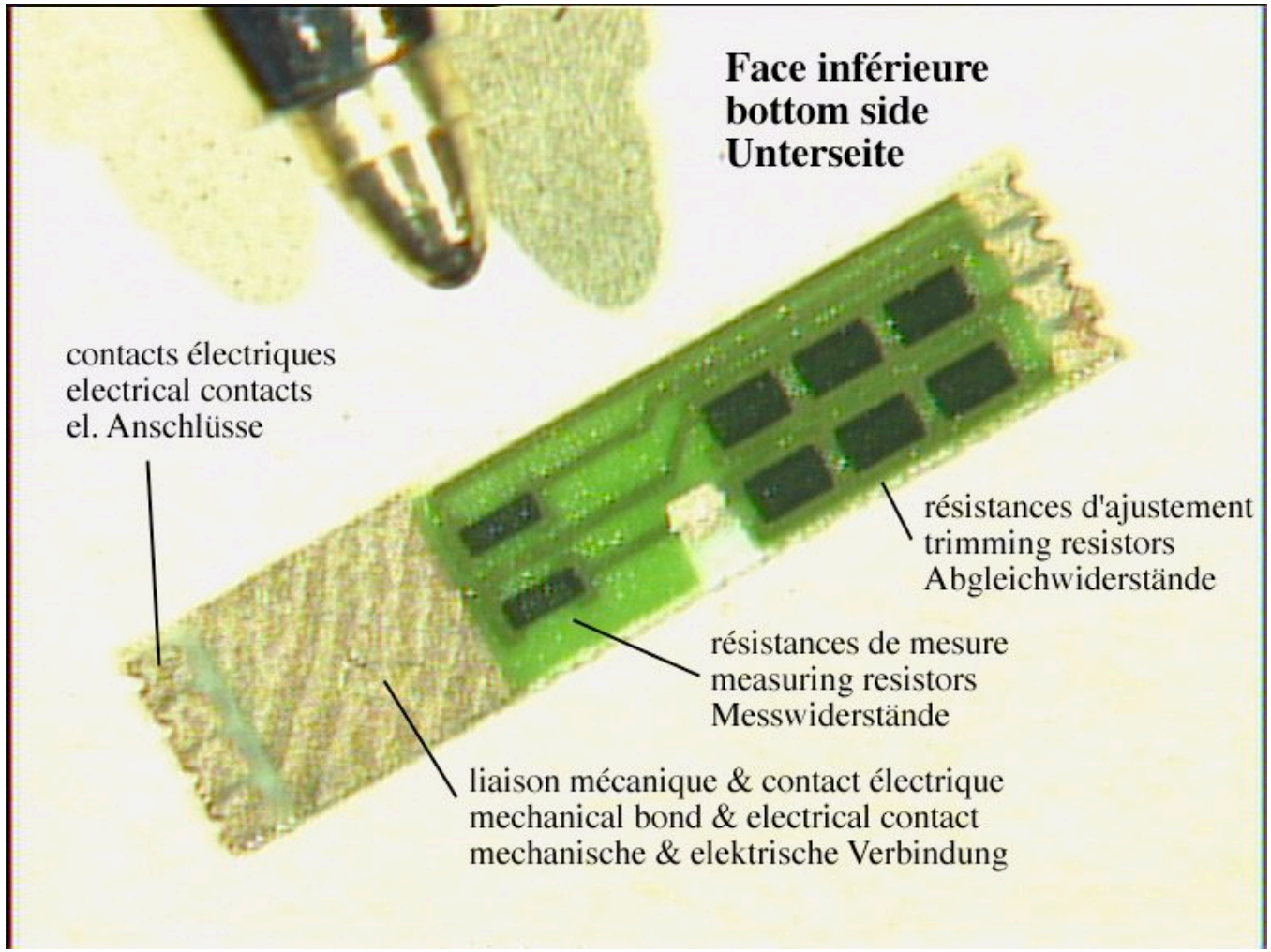
SENSILE TECHNOLOGIES

Principle: a simple force cell



Alumina cantilever

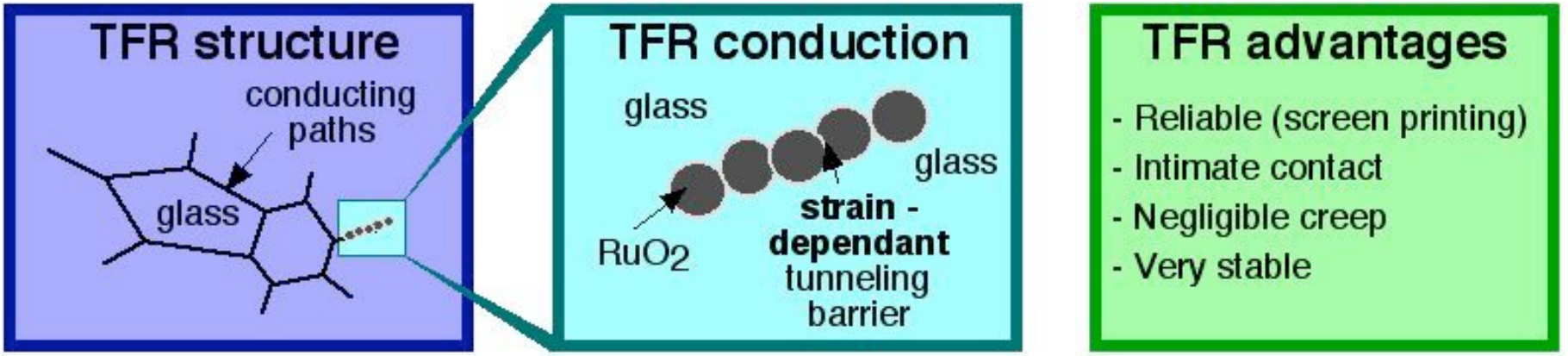


Piezoresistive thick-film sensors

Thick-film resistors posess a **piezoresistive effect**.

Gauge factor = rel. variation / strain = $(\Delta R/R) / \varepsilon$

The **gauge factor** is typ. 12.
(Si : 50)
(metal *DMS - Dehnmessstreifen* : 2)



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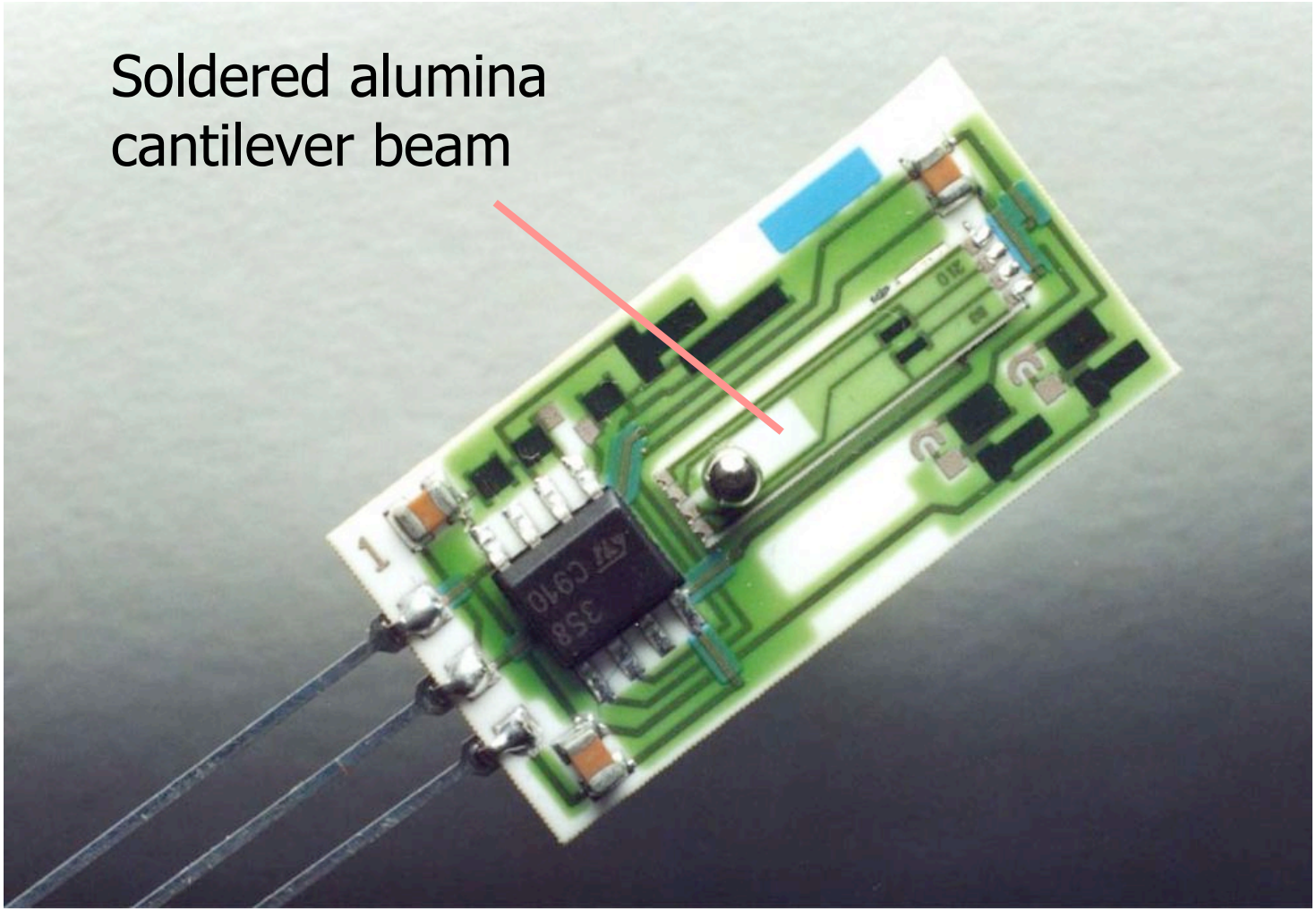
Product: force sensor



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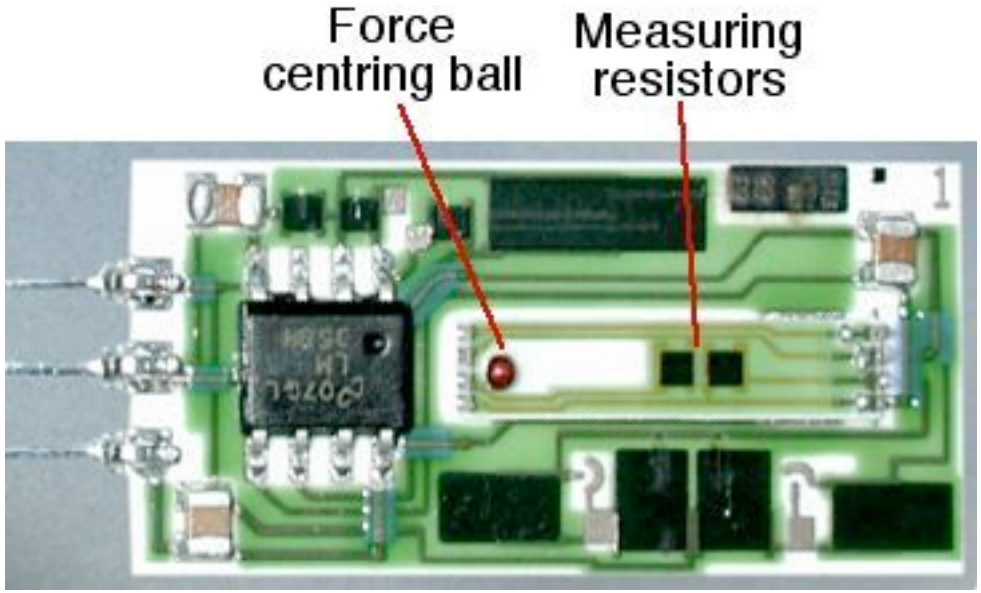
Product: force sensor



Stressed films

1. Terminations / conductor lines.
2. Measuring resistors.
3. Protective glass.

Improving sensor response?

1. **Resistive composition**. High gauge factor compositions have problems…
2. **Strain**. Needs better material than alumina!

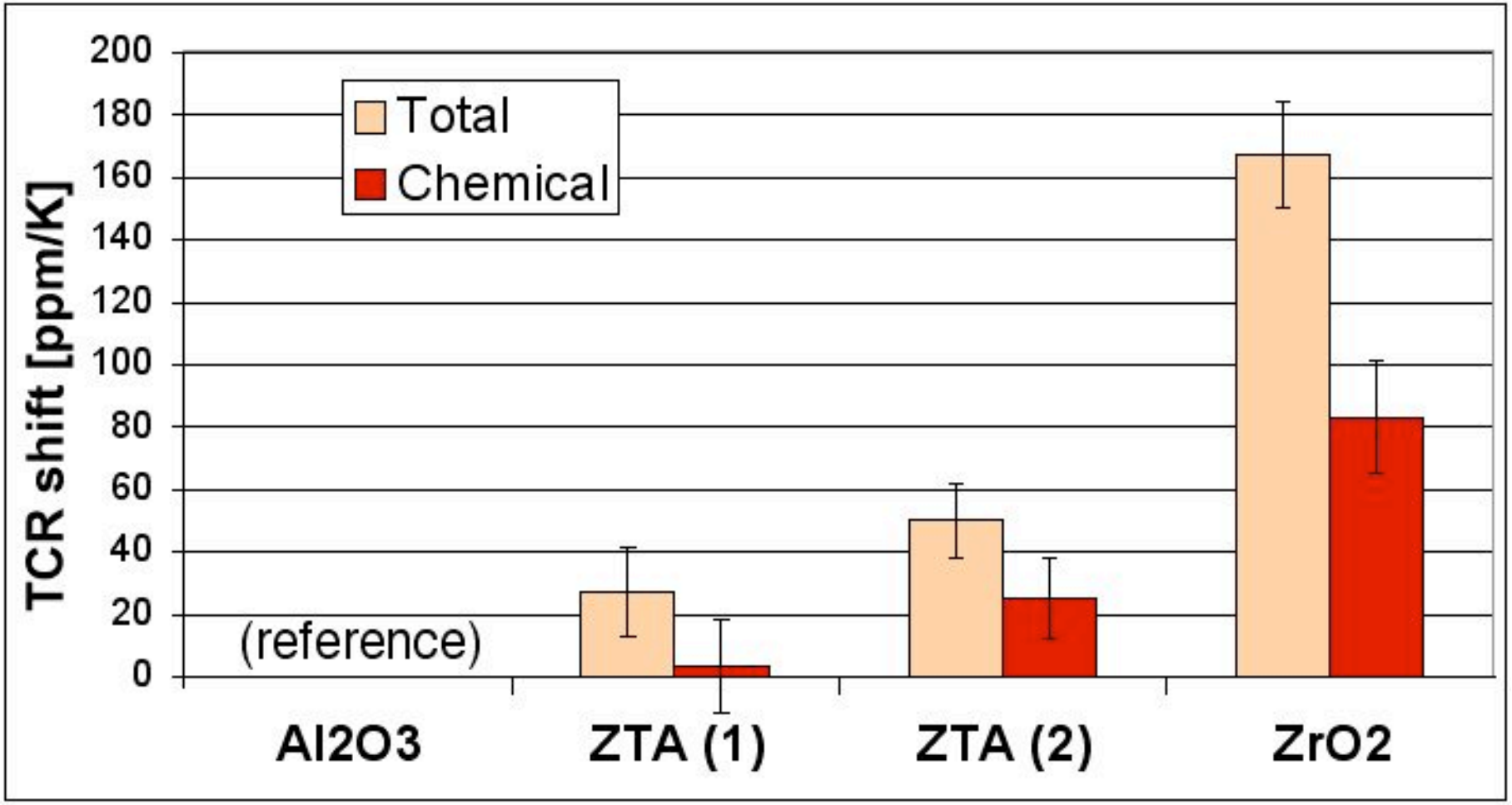
Candidate ceramic materials

1. **High-purity alumina**: slight improvement.
2. **Zirconia**: potentially the best.
3. **ZTA**: Al_2O_3 + ZrO_2: strong & close to alumina.
4. **LTCC**? Not high strength, but other advantages (integration & shape).

Issues with ceramics

- Chemical reactions with thick-film pastes?
- Strain limited by paste failure?
- Thermal expansion - stress and TCR.
- **Weakening of substrate by thick-films**: only tensile stresses really count…
- Weakening by firing schedule: metals, ZrO_2?

Compatibility: Du Pont 2041



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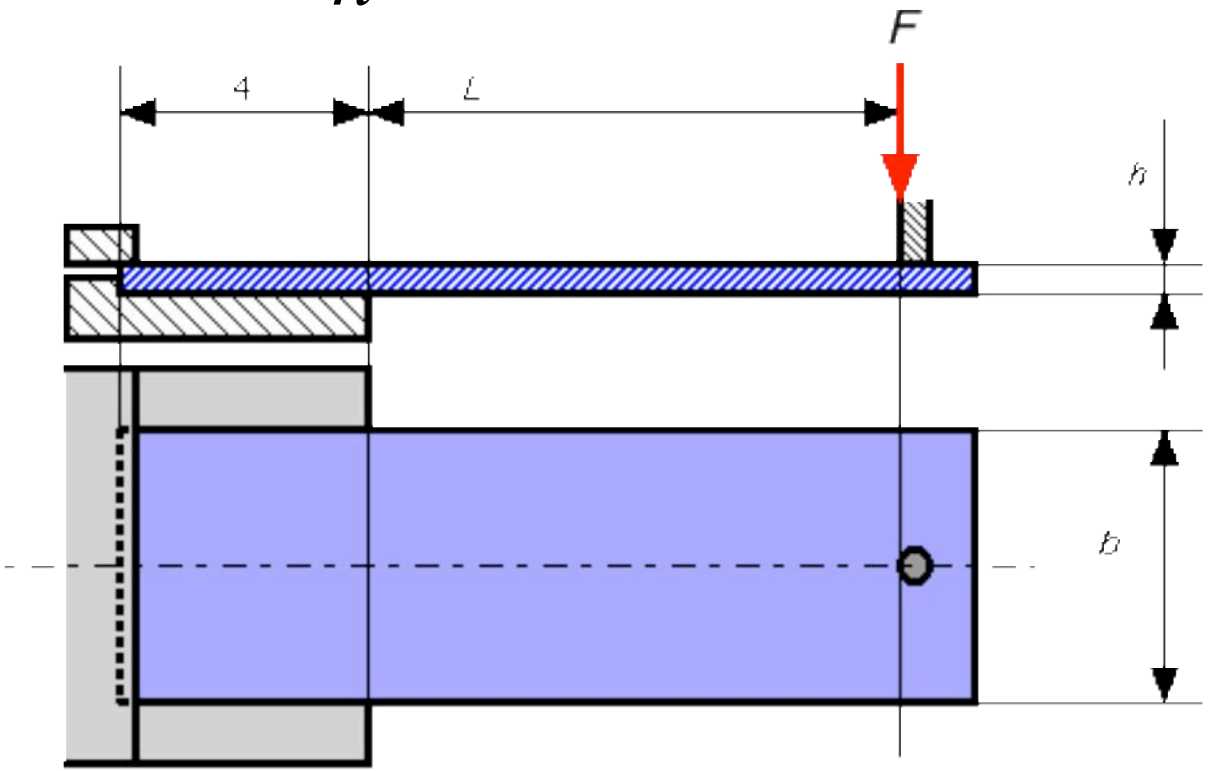
Test setup: long & short-term

$$\sigma_{nominal} = \frac{6F \cdot L}{h^2}$$

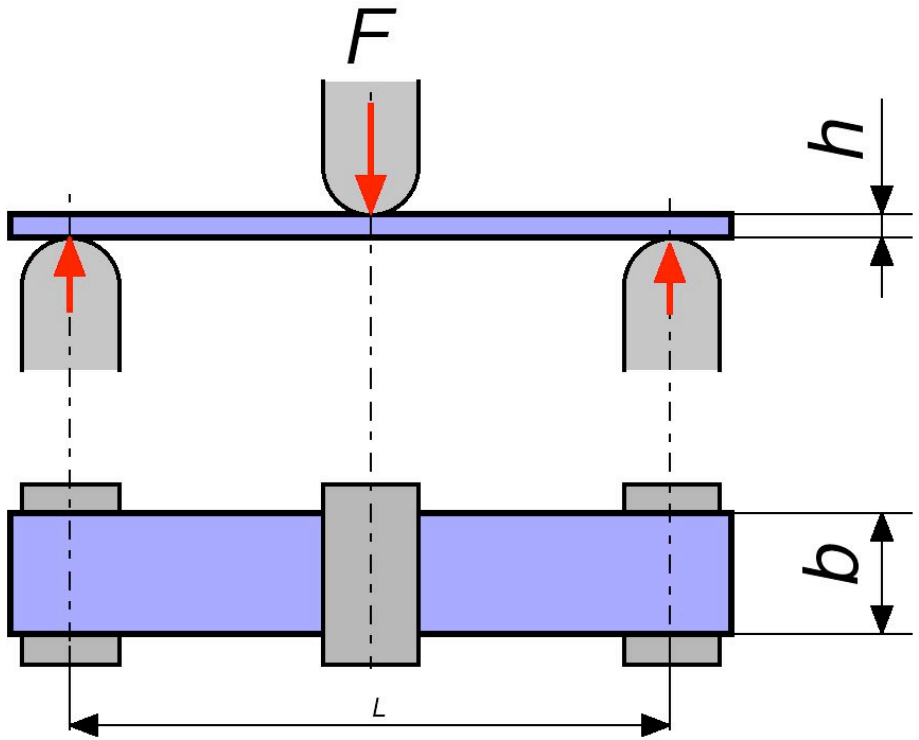
$L \cong 8$; $b \cong 3$; $h \cong 0.25$ mm



Test setup: short-term

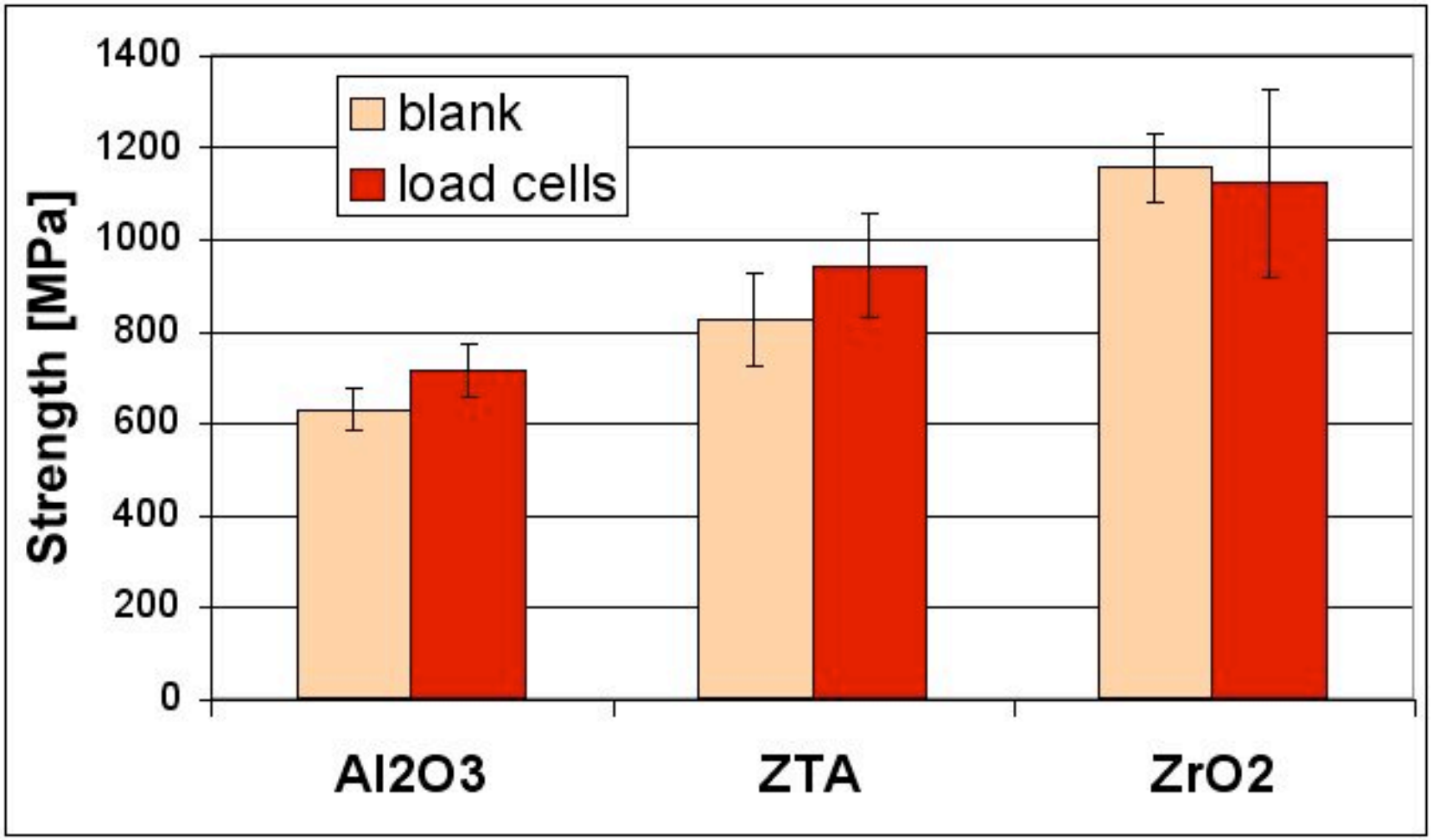
$$\sigma_{nominal} = \frac{3F \cdot L}{2b \cdot h^2}$$

$L \cong 40$; $b = 10.7$; $h \cong 0.25$ mm



Blank and screen-printed

(Short-term, stress)



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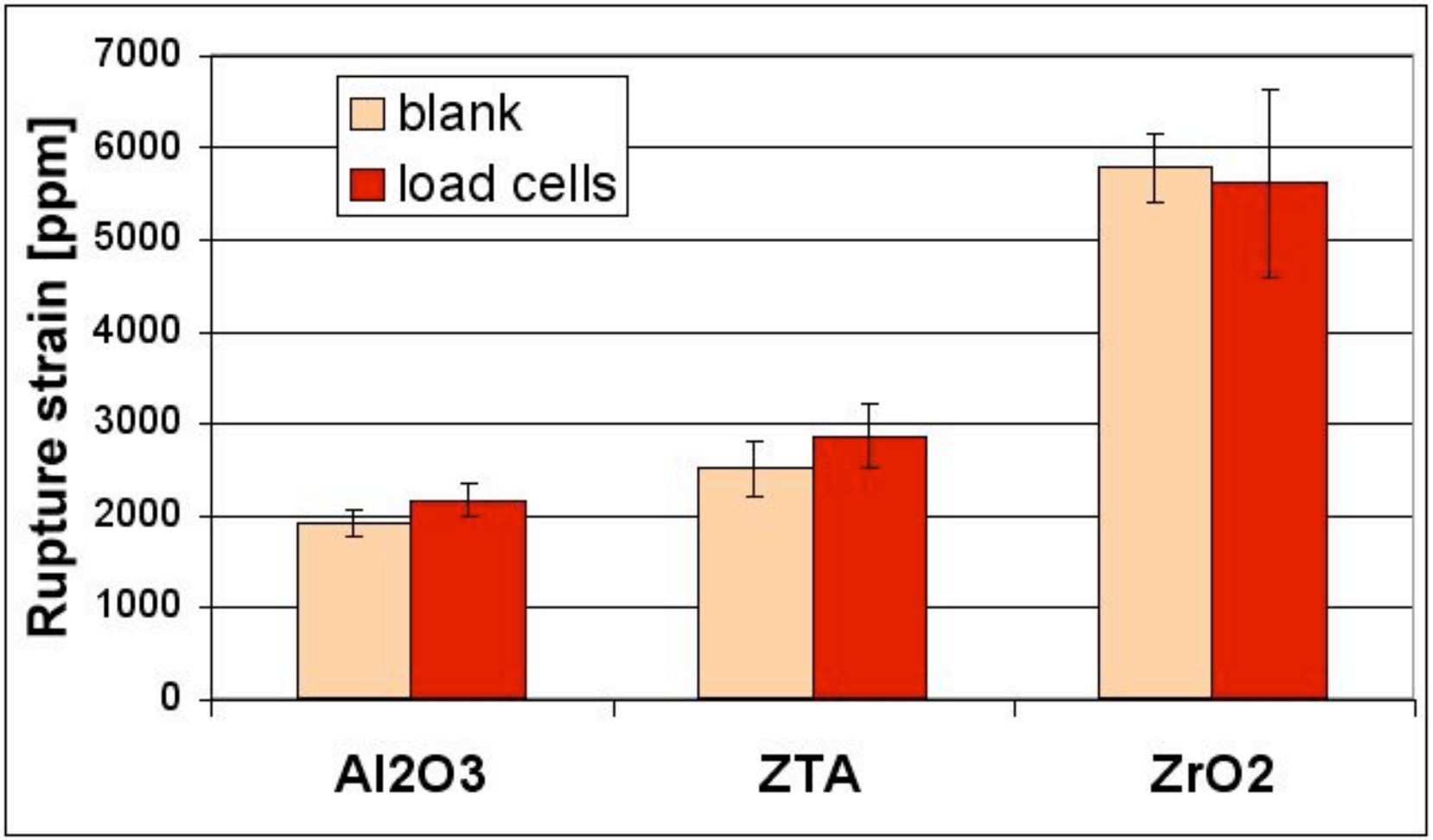
Blank and screen-printed

(Short-term, strain)



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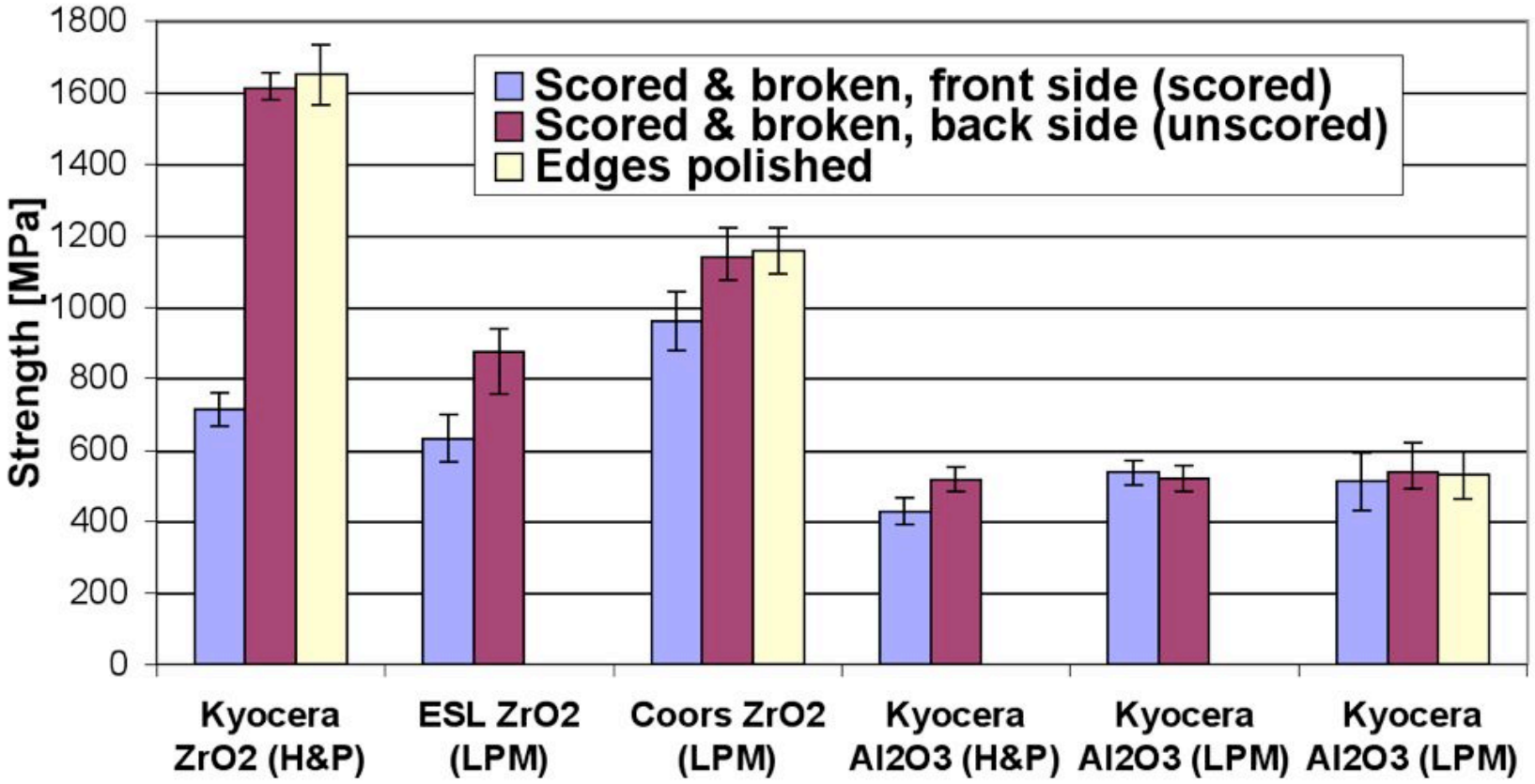
Effect of scoring & breaking

(Short-term)



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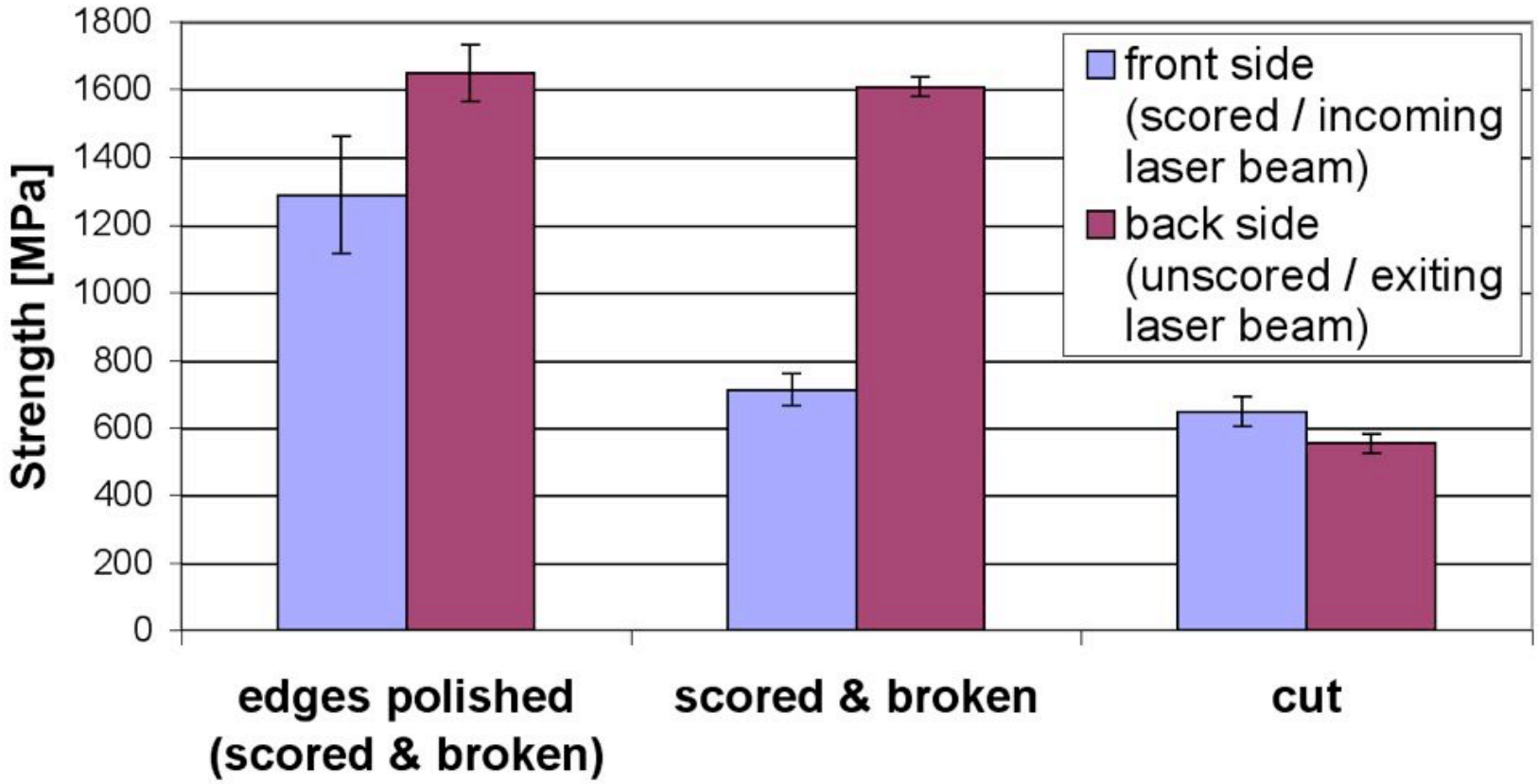
Effect of scoring or cutting

(Zirconia, short-term)



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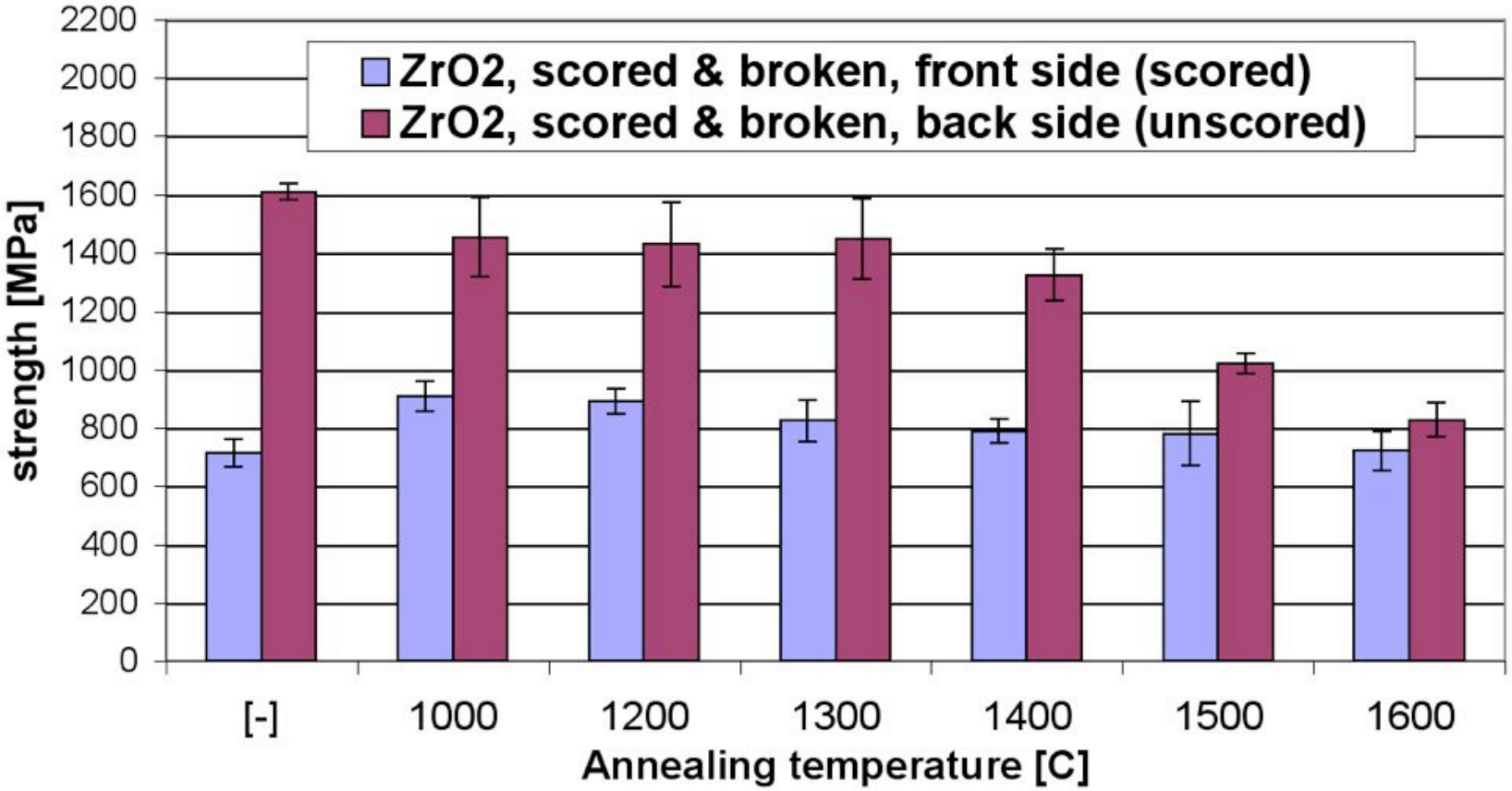
Scored zirconia: annealing

(Short-term)



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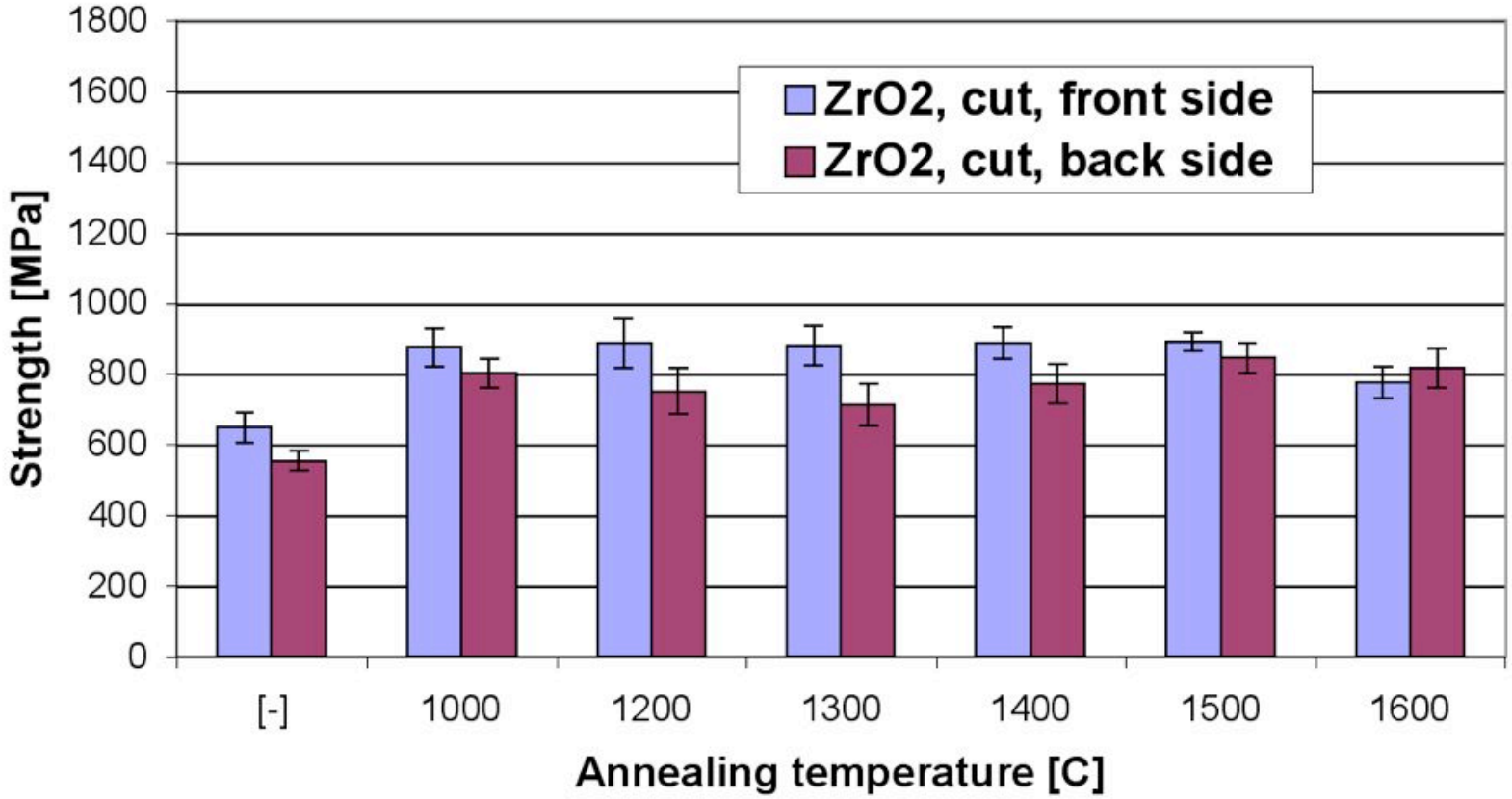
Laser-cut zirconia: annealing

(Short-term)



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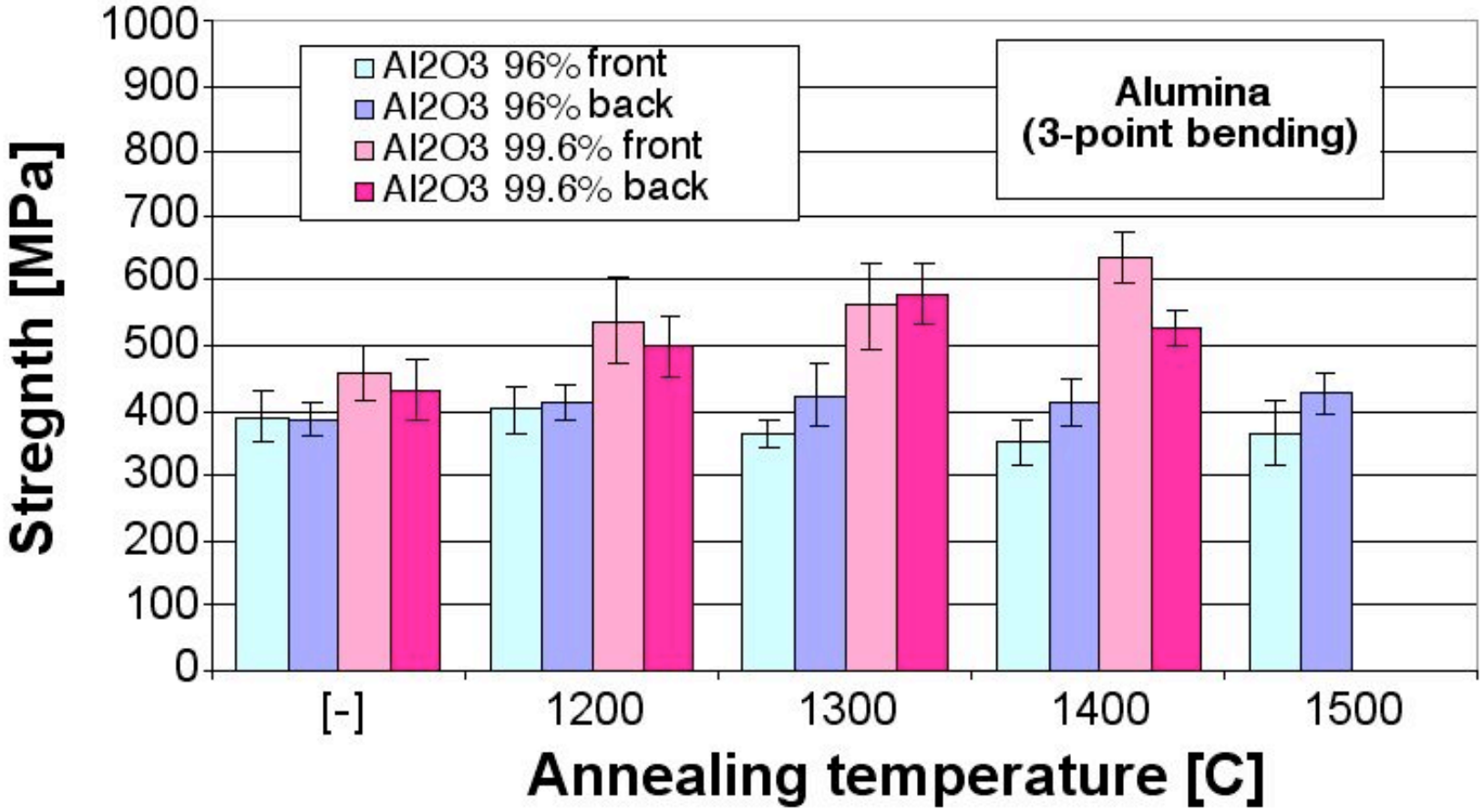
Laser-cut alumina: annealing

(Short-term)



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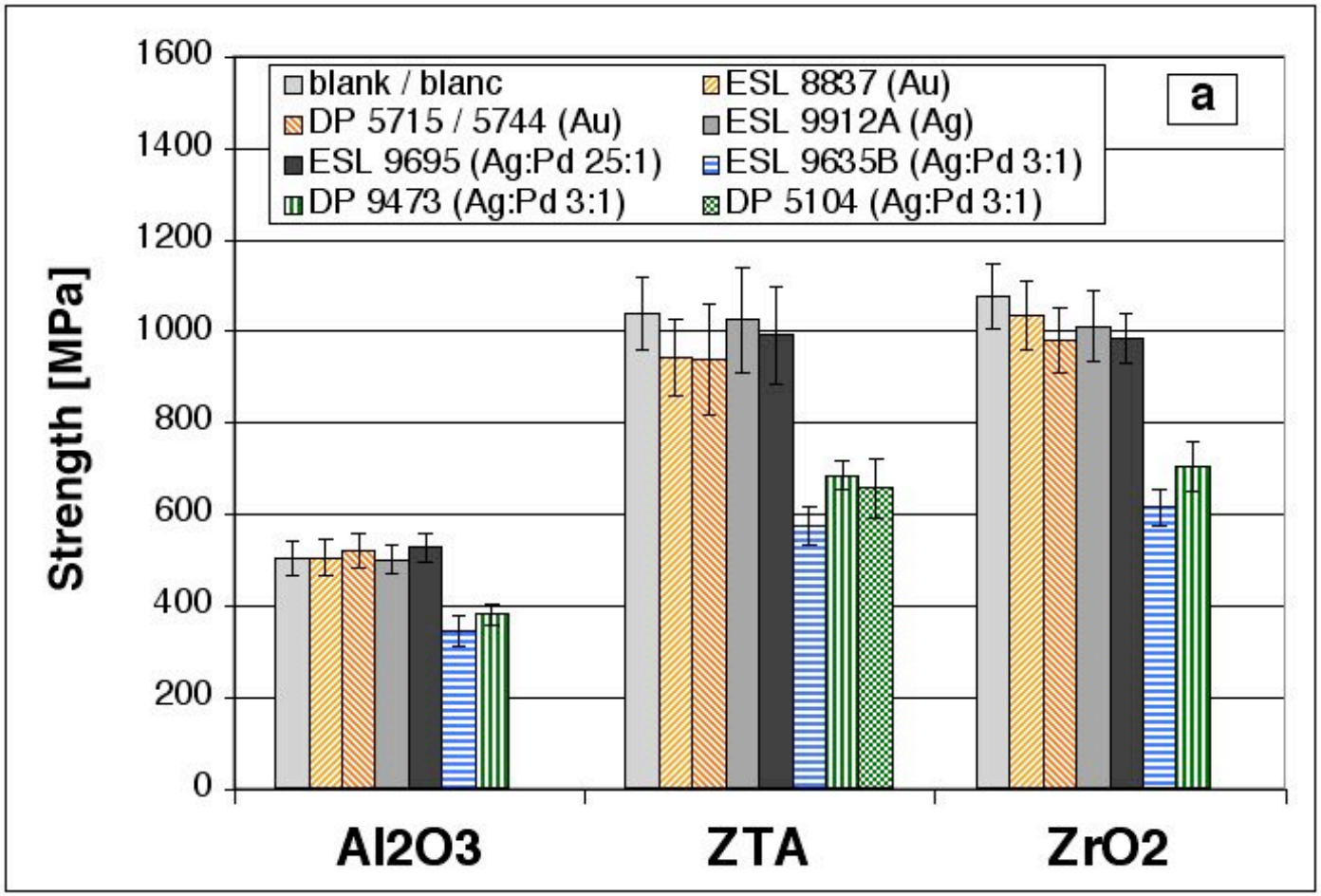
SENSILE TECHNOLOGIES

Effect of metals on strength

(Short-term, absolute)



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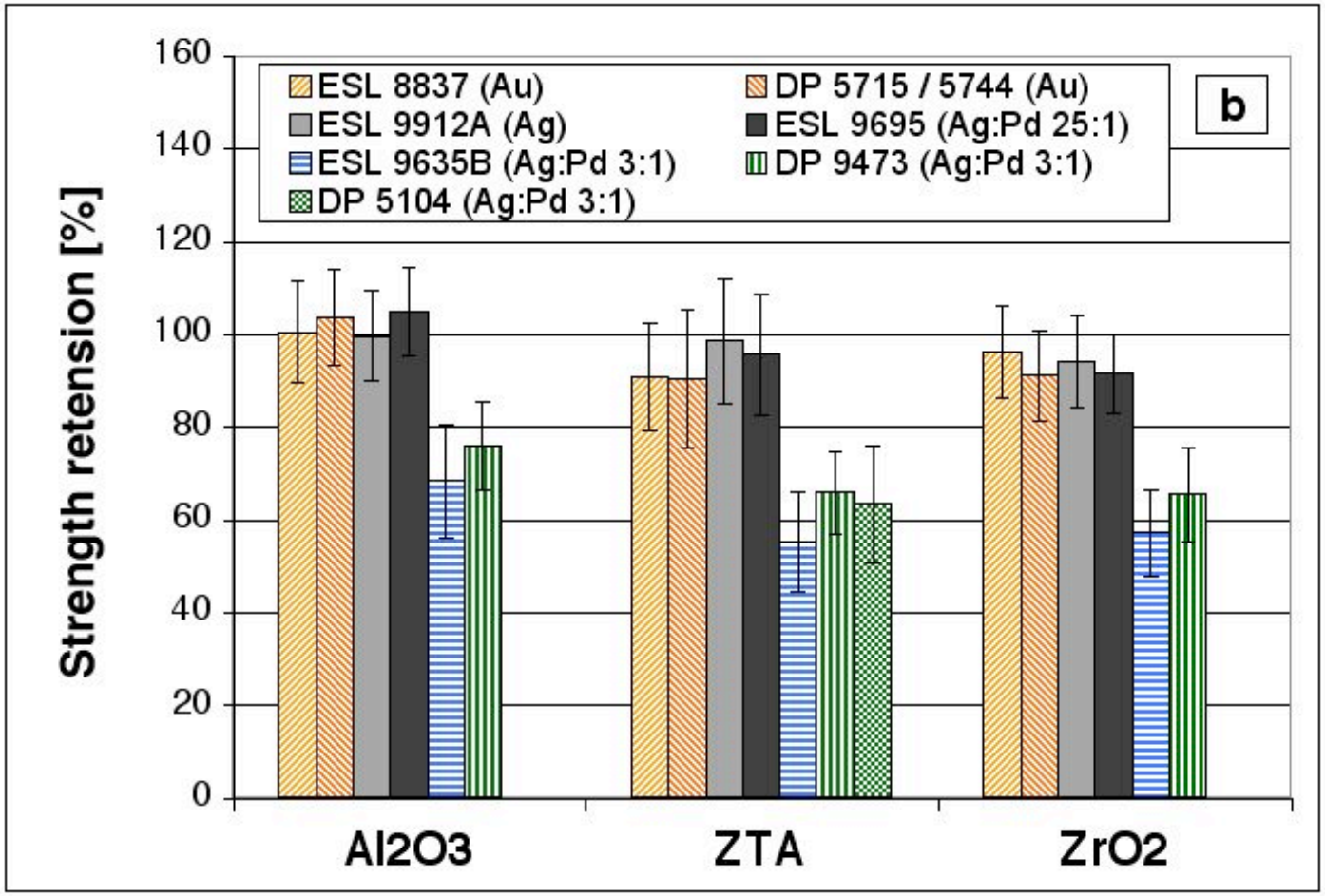
Effect of metals on strength

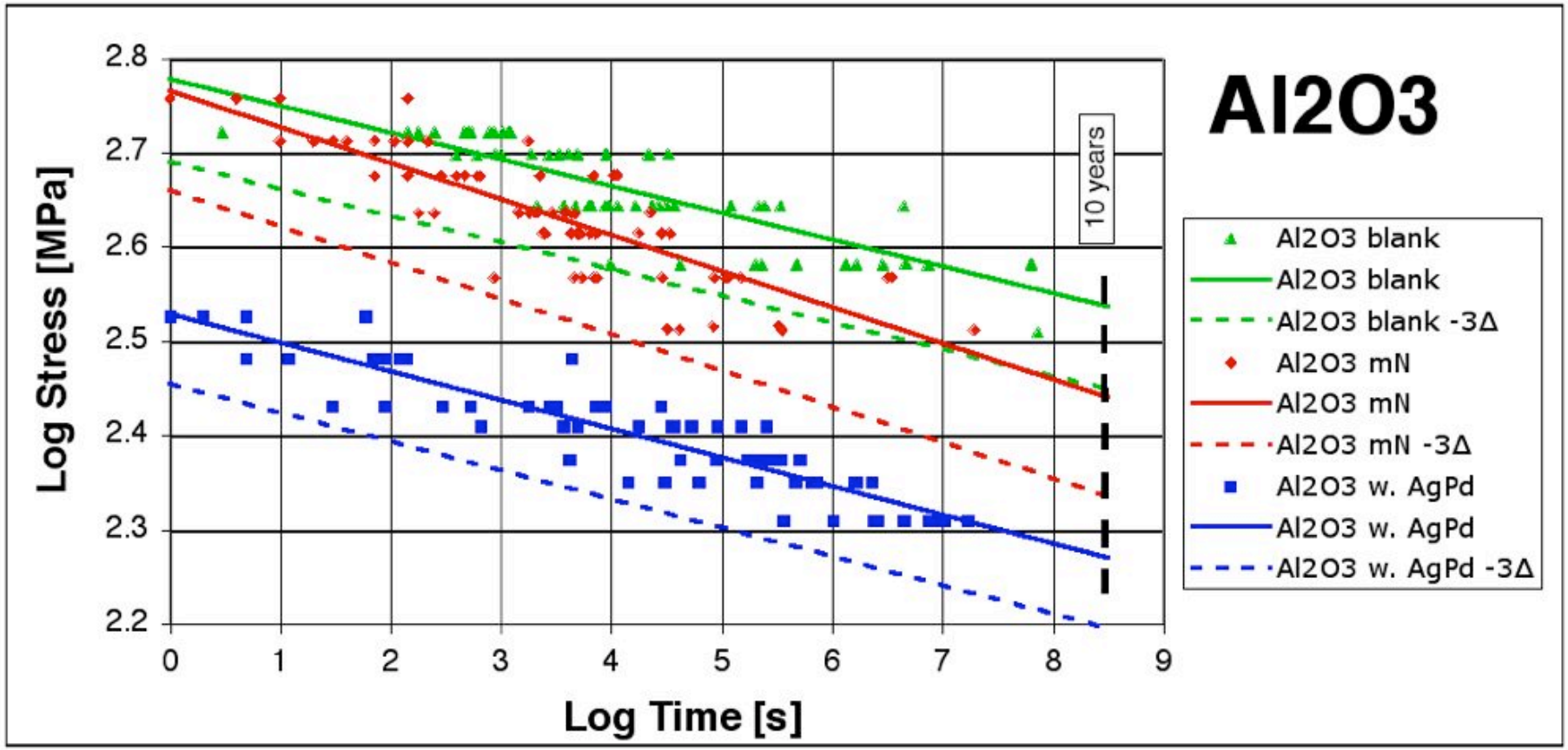
(Short-term, relative)



Summary: short-term results

- ZrO_2 has potentially highest signal, but compatibility problems: TCR shift.
- ZTA is « drop-in » improvement over Al_2O_3.
- Films & processing can seriously degrade mechanical properties, especially for high-strength substrates.
- Good choice of materials & processing: little or no degradation of short-term strength.

Long-term strength



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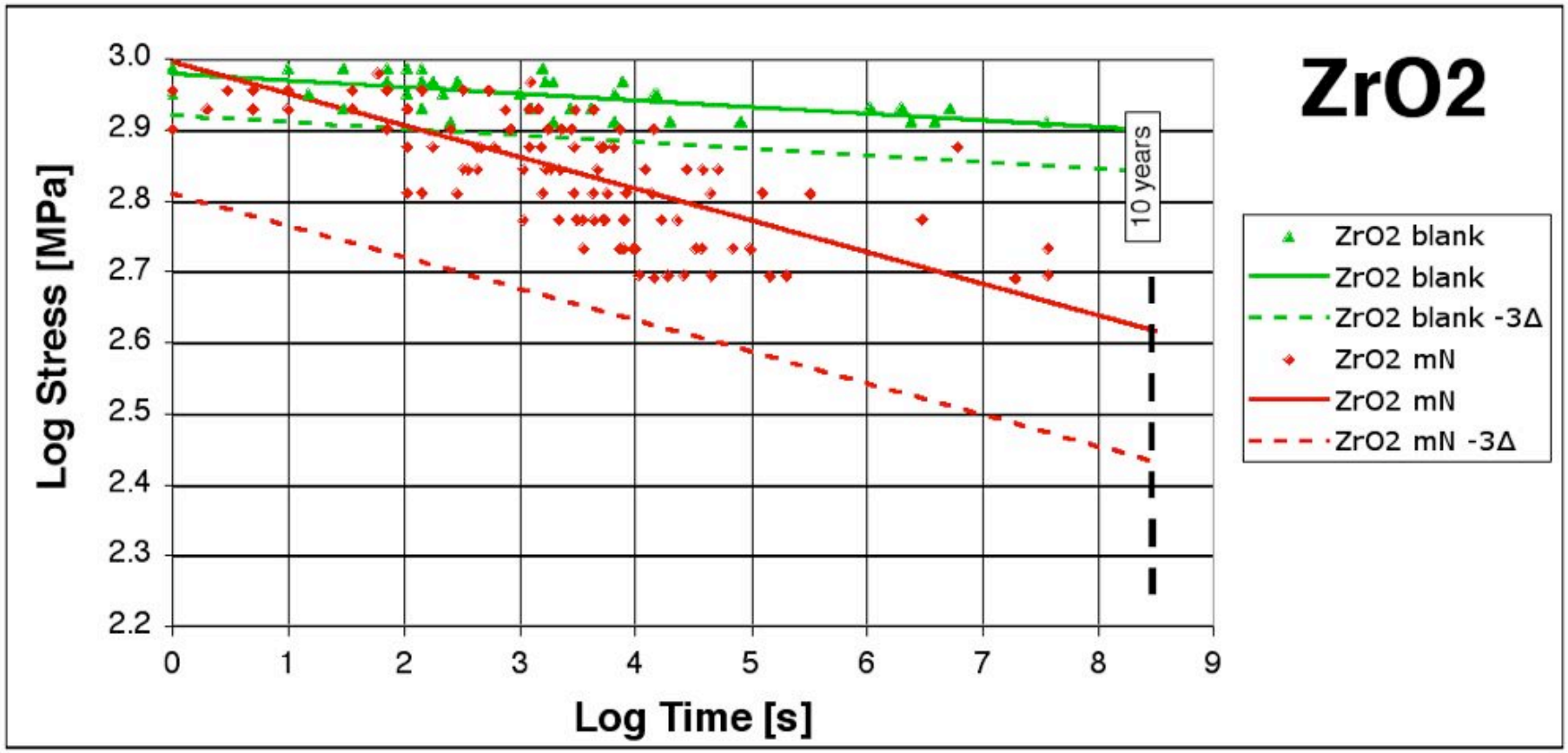
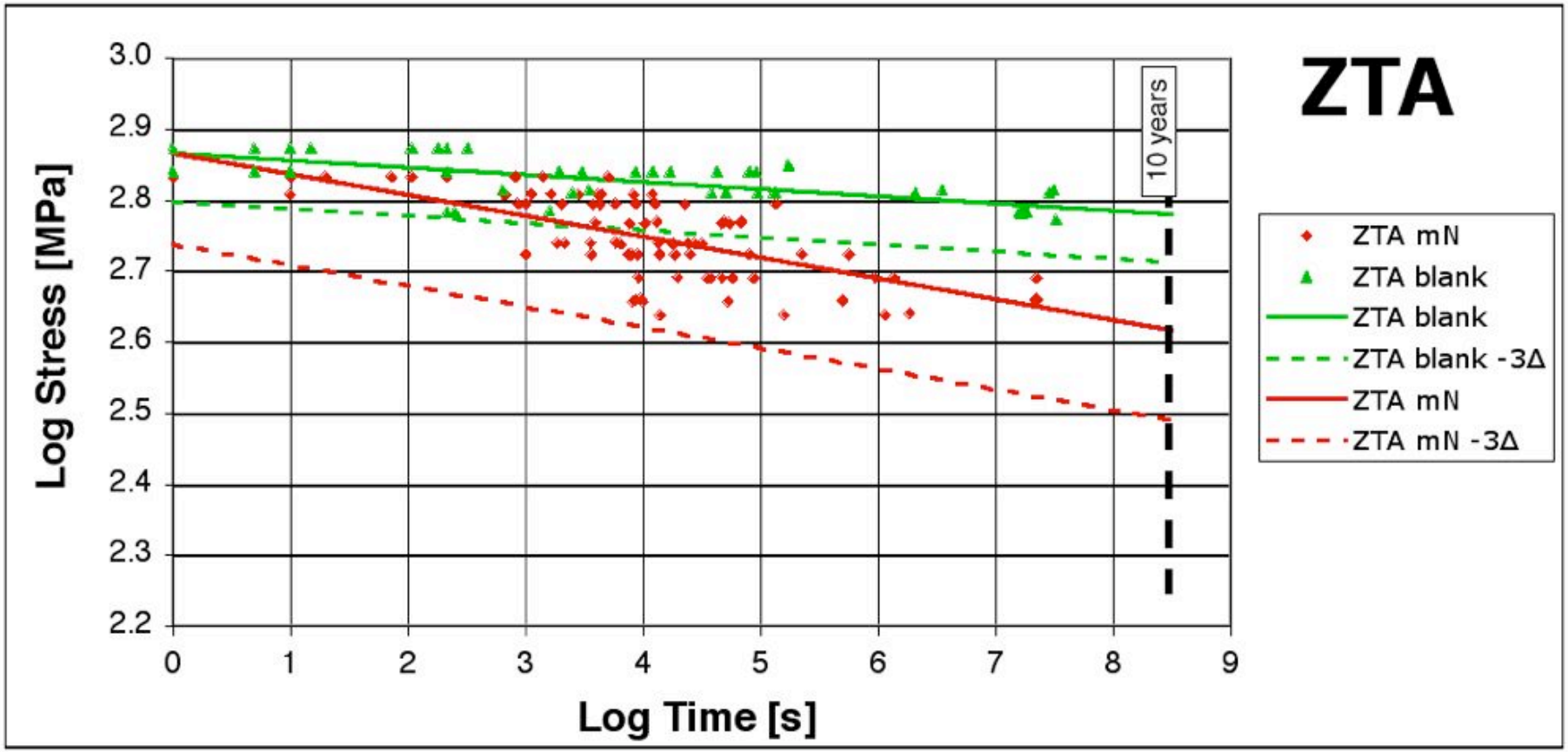
Long-term strength



Long-term strength



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Strength: conclusion

- Little or no short-term degradation.

- Static fatigue properties degraded.

⇒ **Still room for improvement!**